Transverse Single Spin Asymmetry Measurement with J/Ψ in Polarized p+p Collisions at RHIC

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Abstract. The PHENIX experiment has measured transverse single spin asymmetry of J/Ψ in polarized p+p collisions at forward rapidity at $\sqrt{s} = 200$ GeV. The data were collected from year 2006 run of RHIC with average beam polarization of 56%. At RHIC energy, heavy quark production is dominated by gluon gluon interaction. Therefore, the transverse single spin asymmetry in J/Ψ production can provide a clean measurement of the gluon Sivers distribution function.

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INTRODUCTION

The measurement of transverse single spin asymmetries gives us an opportunity to probe the quark and gluon structure of transversely polarized nucleons. Large transverse single spin asymmetries of up to 20% - 40% were observed for pions produced at large x_F at $\sqrt{s}$ = 20 GeV[1] and have been found to persist at $\sqrt{s}$ = 200 GeV by the STAR [2] and BRAHMS[3] experiments, although they were expected to vanish in pQCD calculations at the leading order. A number of pQCD based models have been developed to explain this phenomena. Among them are the Sivers effect (transversely asymmetric k_T quark and gluon distributions)[4], the Collins effect (transversity distribution in combination with spin-dependent fragmentation function)[5], and the higher twist effect (interference between quark and gluon fields in the initial or final state)[6, 7].

At RHIC energy, heavy flavor production is dominated by gluon-gluon interaction, thus Collins effect has minimum impact on A_N as the gluon's transversity is zero. Therefore, the production of heavy flavor particles in transversely polarized p+p collisions at the PHENIX experiment offers a good opportunity to probe the gluon's Sivers effect.

MEASUREMENT AND ASYMMETRY CALCULATION

In this report we present the latest results of transverse single spin asymmtery in J/Ψ production in polarized p+p collisions at RHIC. The PHENIX muon spectrometers has measured J/Ψ yields through the J/$\Psi \rightarrow \mu^+\mu^-$ channel at forward rapidities ($1.2 < |\eta| < 2.4$). During the recent 2006 polarized pp run, the PHENIX experiment has collected 2.7 pb^{-1} data with transverse beam polarization about 56%. The Level-2 dimuon triggered data sample has been used in this analysis.

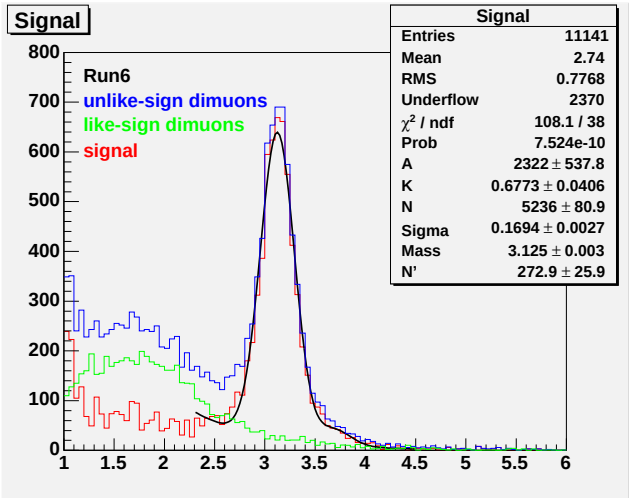

FIGURE 1. Dimuon invariant mass distribution.

The J/Ψ yield is obtained by fitting the dimuon mass spectrum with a single exponential background plus two gaussian functions (for J/Ψ and Ψ′) in the mass range 2.3 GeV - 4.5 GeV (as shown in figure 1). The total Number of J/Ψ from this fit is 5236 ± 81. The Monto Carlo simulation shows the systematic error in determining J/Ψ yield is less than 2%.

The transverse single spin asymmetry A_N can be determined by:

$$A_N = \frac{1}{P_b}\frac{\sigma^{\uparrow} - \sigma^{\downarrow}}{\sigma^{\uparrow} + \sigma^{\downarrow}} = \frac{1}{P_b}\frac{N^{\uparrow} - RN^{\downarrow}}{N^{\uparrow} + RN^{\downarrow}}, \tag{1}$$

where P_b is the beam polarization, $\sigma^{\uparrow}(\sigma^{\downarrow})$ is the production cross section, $N^{\uparrow}(N^{\downarrow})$ is the J/Ψ yield from up(down) polarized bunches, and $R = L^{\uparrow}/L^{\downarrow}$ is the relative luminosity of bunches of opposite polarization sign. The relative luminosity is measured by two global detectors, BBC and ZDC.

Alternatively, we also use square root formula

$$A_N = \frac{1}{P_b}\frac{\sqrt{N_L^{\uparrow} \cdot N_R^{\downarrow}} - \sqrt{N_L^{\downarrow} \cdot N_R^{\uparrow}}}{\sqrt{N_L^{\uparrow} \cdot N_R^{\downarrow}} + \sqrt{N_L^{\downarrow} \cdot N_R^{\uparrow}}}, \tag{2}$$

to cross check our results.

The asymmetry of J/Ψ was determined for each fill using Eq. (1), then averaged over all fills.

The raw J/Ψ sample is contaminated by other background, mainly comes from Drell-Yan process, open charm and light hadrons decay. The $A_N^{J/\Psi}$ was corrected for the contribution of background by using

$$A_N^{J/\Psi} = \frac{A_N^{incl} - r \cdot A_N^{BG}}{1 - r}, \tag{3}$$

$$\delta A_N^{J/\Psi} = \frac{\sqrt{(\delta A_N^{incl})^2 + r^2 \cdot (\delta A_N^{BG})^2}}{1-r}, \tag{4}$$

where r is the background fraction under the J/Ψ peak, A_N^{BG} the averaged background asymmetry. A_N^{BG} is obtained using the like (unlike) sign dimuon pairs within 2.0 GeV$<$ $M_{\mu\mu} < 2.5$ GeV, , and like sign dimuon pairs within 2.8 GeV$< M_{\mu\mu} < 3.5$ GeV.

The systematic uncertainty has been checked with bunch shuffling technique with randomly assigned beam polarizations for each fill. The bunch-to-bunch and fill-to-fill systematic errors are much smaller than the statistical errors for this data set.

RESULTS

The asymmetry was calculated for two x_F bins. Figure 2 shows the preliminary result of the single spin asymmetry as a function of x_F in J/Ψ production from the 2006 RHIC transverse run. A scale uncertainty of 20% due to the absolute polarization values is not included in this analysis. Within the limits of errors, A_N is consistent with zero over the measured x_F range.

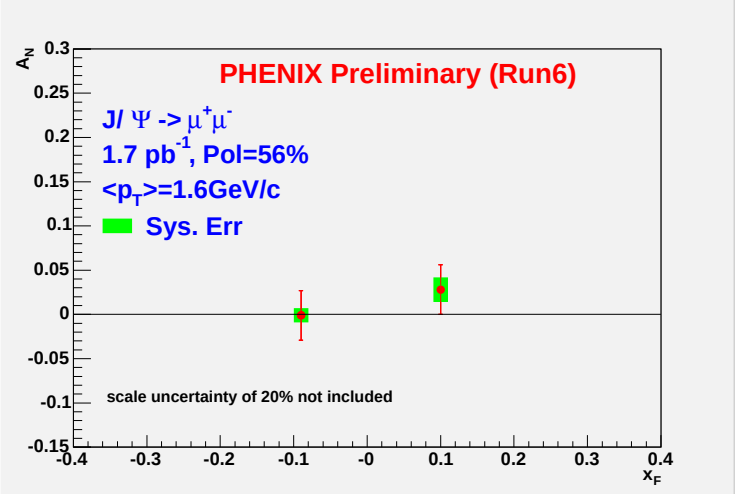

FIGURE 2. Transverse single spin asymmetry vs. x_F for J/Ψ at forward rapidities. A scale uncertainty of 20% is not included.

Currently there is no theoretical calculation of J/Ψ's A_N. However, there is prediction of maximum values of $|A_N|$ in D meson production at fixed transverse momentum $p_T = 1.5$ GeV/c at RHIC energy, as shown in figure 3[8]. The solid line shows $|A_N|_{max}$ when the gluon Sivers function is set to its maximum with the quark Sivers function set to zero, and the dashed line corresponds to a maximized quark Sivers function with the gluon Sivers function set to zero. If the transverse single spin asymmetry comes from the initial state (the J/Ψ production mechanism does not play an important role), then we expect A_N in J/Ψ and D meson production should be very similar. The fact that there is no sizable asymmetry observed in figure 2 may indicate our result disfavor the maximum contribution of gluon's Sivers function.

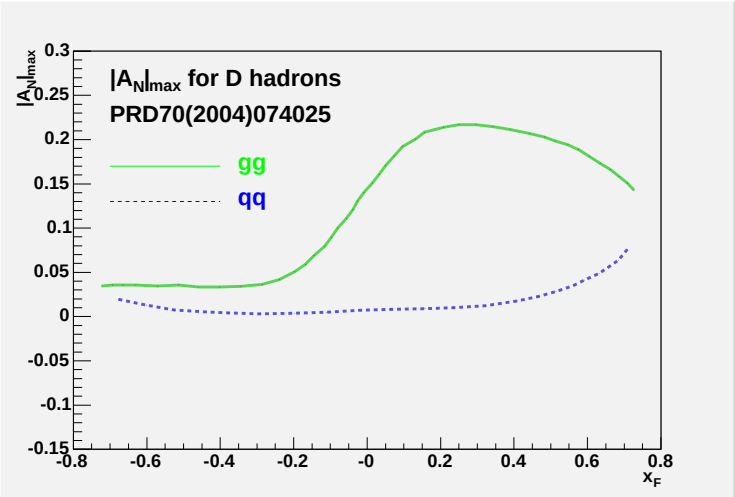

FIGURE 3. Maximized values of $|A_N|$ for the process p+p→DX as a function of x_F at fixed transverse momentum $p_T = 1.5$ GeV/c at RHIC energy.

SUMMARY

The transverse single spin asymmetry A_N for J/Ψ has been measured for the first time at forward rapidity and $\sqrt{s}$ = 200 GeV in with the PHENIX muon spectrometers. Using Level-2 dimuon triggered data sample (corresponds to 60% of the whole 2006 transverse data set), no sizable A_N of J/Ψ has been observed which indicates our result disfavor the maximum gluon Sivers contribution.

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